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Miners' Nystagmus and Incapacity for Work: A Clinical Study Based on an Analysis of 512 Cases

An Improved Form of Burstein Apparatus for Determination of the Dust Coefficient of the Air

Modified Design of Hay Dust Trap

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THE JOURNAL OF INDUSTRIAL HYGIENE

VOLUME XII JANUARY, 1930 NUMBER 1

MINERS' NYSTAGMUS AND INCAPACITY FOR WORK: A CLINICAL STUDY BASED ON AN ANALYSIS OF 512 CASES*

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INTRODUCTION

ALTHOUGH miners' nystagmus has been recognized since the year 1861, it was described by C. Bell Taylor as a new disease in 1875, and since that time it has received the focused attention of many observers, and a large amount of literature has been published concerning the various aspects of the disease.

The Miners' Nystagmus Committee of the Medical Research Council added considerably to our knowledge by its reports in 1922 and 1923, in which are found statistics in regard to the various etiologic factors concerned in the occurrence and incidence of miners' nystagmus, as well as a general description of the disease, with observations on the incapacity resulting therefrom.

In many ways, however, our knowledge of the subject is still far from complete, and there is a wide field open for future study and research. One of the problems requiring further investigation appeared to me to be the exact relationship between miners' nystagmus and incapacity for work, particularly in regard to the following points:

1. What relation does defective vision in an underground worker bear to (*a*) the age at which miners' nystagmus develops, (*b*) the length of time spent at underground work before the disease appears, and (*c*) the period of incapacity for work that results?

2. (*a*) When may a recurrence of the disease be expected after the man returns to underground work; and (*b*) does the second attack result in a longer period of incapacity than the first attack?

3. (*a*) What is the relationship between the age of the man and the period of incapacity caused by the disease? (*b*) Has the age any influence on the liability to re-

*Based on a thesis accepted for the degree of M.D. by the University of Wales. Received for publication Oct. 3, 1929.

currence of the disease, and on the severity of the recurrences?

4. Do the cases with marked neurasthenic symptoms develop the disease sooner than other cases?

5. What is the average period of incapacity for work in a case of miners' nystagmus if observed for some years after first becoming incapacitated by the disease?

With the object in view of obtaining information that would help to elucidate some of these problems, I examined 512 cases of miners' nystagmus and analyzed them in considerable detail. This analysis is supplemented by clinical observations on the oscillations of the eyes, individual cases of interest, and groups of cases illustrating particular points.

Analysis of 512 Cases

These cases, which were examined during the period 1921 to 1929, were drawn from various sources in the South Wales coal field, not from any particular colliery. Their distribution according to underground occupation was as follows:

Collier	402
Haulier	39
Repairer	28
Timberman	15
Laborer	11
Ripper	5
Rider	3
Collier's helper	2
Bottom cutter	1
Hitcher	1
Roadman	1
Inclinesman	1
Pumpsman	1
Traffic man	1
Borer	1
Total	512

The proportion of coal face workers to all underground workers is taken as 60 per cent. in the report of the Miners' Nystagmus Committee in 1922; the proportion of colliers in this series of cases of nystagmus is 78.5 per cent., which corresponds nearly with the proportion of cases among coal face workers to all cases of nystagmus in the report referred to above, which was 81.5 per cent.

There is apparently a great tendency for the disease to appear in coal hewers, but it evidently also occurs with some frequency in hauliers, repairers, and timbermen, and is by no means confined to the hewers.

The average age in this series at which the disease first caused incapacity for work was 41.01 years for the 512 cases. This, however, is not to be regarded as a time of life when the disease may be expected to develop, as in so many cases the patients are young, and in so many others they are old. Table 1 shows the proportion at various ages in this series: 75.7 per cent. developed the disease between 30 and 60 years of age, while 18.7 per cent. were affected before 30 years of age.

The youngest patient was a boy of $16\frac{1}{2}$ years, and the oldest was 71 years when the disease first appeared; whereas the older man had worked the great part of his life underground, the younger had worked just two and one-half years underground, as a collier's helper. This indicates that the onset of the disease has no relation to the length of time that a man has worked underground.

The average time worked underground, based on 192 cases throughout the series, was 27.3 years. Among these, eighty-three had both eyes normal and eighty-eight had both eyes defective, and the time worked underground averaged 27.1 years and 27.9 years, respectively.

These figures correspond so closely that one can only conclude that defective eyesight in an underground worker does not render him likely to develop miners' nystagmus sooner than a man with good sight. This point is further demonstrated by the fact that in the whole series there were 234 with both eyes normal, 230 with both eyes defective, and twenty-eight with one eye defective.

TABLE 1.—AGE DISTRIBUTION OF 512 CASES OF MINERS' NYSTAGMUS

AGE	NO.	PER CENT.
Under 20	11	2.1
20–29	85	16.6
30–39	134	26.2
40–49	141	27.5
50–59	113	22.1
60 and over	28	5.5
Total	512	100.0

For the purpose of this analysis, a man was deemed to have both eyes normal if there was no appreciable error of refraction, or if the error was so slight as to cause neither materially defective vision nor eyestrain. Thus, a man with −0.75D. of myopia in each eye was not classed as having both eyes defective, whereas a man with −2D. of astigmatism was so termed, the classification being made essentially for the purpose of determining how great was the effect on the disease of materially defective sight, or of definite eyestrain from optical causes.

The longest period worked underground before nystagmus developed was fifty-eight years. Following are notes regarding three men, each of whom had worked underground a long time before the disease appeared:

CASE 1.—Worked underground forty-seven years. Vision 2/60 in each eye, as a result of macular disease which had developed during the past four years.

CASE 2.—Worked underground fifty-seven years. Vision in right eye with +0.75 D. Sph. = 6/12; vision in left eye = 6/12. He had had trouble with his eyes for only six months, and he showed oscillations of the eyes.

CASE 3.—Worked underground fifty-eight years. Vision 6/18 with +0.5 D. Cyl. Axis 90° = 6/12.

The first of these three men probably had normal eyesight until a year or two before he developed nystagmus, but two years after giving up work there were no signs of nystagmus, the disease having cleared in spite of increasing defective vision. The other two men had good sight all their lives, and this fact rather militates against the idea that in the first case the onset of nystagmus was occasioned by the development of macular disease.

Miners' nystagmus is of considerable importance in the economics of the South Wales coal industry, and in this series there are records of 140 cases in which the disease had been present for more than five years prior to the last examination. Table 2 shows to what extent incapacity for work was present in these cases.

TABLE 2.—INCAPACITY FOR WORK IN 140 CASES OF MINERS' NYSTAGMUS

PERIOD	TOTAL YEARS	AVERAGE YEARS
Since disease first caused incapacity	1,275	9.10
Total incapacity	293	2.09
Worked underground since disease first caused incapacity	475	3.39

Apparently the average nystagmus patient does not work underground more than a third of his time after developing the disease and becoming incapacitated thereby. This throws an additional burden on the coal industry; in fact a person affected with nystagmus finds it difficult to obtain employment, particularly underground, once he has been certified as suffering from the disease.

It is recognized that incapacity is likely to be more prolonged when the industry is not flourishing, and I have to note that many of the cases in this series occurred at a time when the coal industry in South Wales was not at its best. In better times the period of incapacity for work might be less.

The period of total incapacity with a first attack of miners' nystagmus and the combined period of total and partial incapacity—the number of years before resuming work underground after a first attack—are shown in Table 3. The averages for the different types of cases correspond so closely as to make it evident that the state of vision does not influence the period of total incapacity or the combined period of total and partial incapacity.

A question which is often asked by the collier disabled by nystagmus and recovering from his first attack is, "Do you advise me to go back to underground work?" An investigation of the number of years worked underground in 113 cases before developing a second attack of nystagmus showed a total of 398 years, or an average of 3.52. Comparing this period with the average period worked underground before becoming incapacitated by nystagmus in the first place—*i.e.*, comparing 3.52 years with 27.39 years—we find not a primary susceptibility to the disease, but a definite proneness to recurrence once the disease has appeared and has caused disability.

TABLE 3.—INCAPACITY FOR WORK WITH A FIRST ATTACK OF MINERS' NYSTAGMUS

TYPE OF CASE	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Period of Total Incapacity			
All types	372	436	1.17
Both eyes normal	166	198	1.19
Both eyes defective	172	202	1.17
Period of Total and Partial Incapacity[1]			
All types	221	534	2.41
Both eyes normal	94	237	2.52
Both eyes defective	107	258	2.41

[1] In this table and in subsequent tables, this period represents the number of years before resuming work underground.

The evidence from this series of cases is, therefore, that if the collier does resume underground work, he is likely to have a second attack in from three to four years. Knowing the discomfort, worry, and anxiety that form only too large a part of the disease, one can hardly advise him to resume his work, though he may be forced to it of necessity.

It is difficult to say exactly what change has taken place in a man to render him prone to a second attack. In some cases it is probable that he returns to work before the disease—apart from the proneness to recurrence—has cleared up. It may be that

oscillations of the eyes cannot be elicited and that there is no blepharospasm nor intolerance of light, and it may be that in the absence of objective signs little notice is taken of many symptoms of which the man may still be complaining. It is well recognized that objective signs of the disease may be elicited one day and not another, and particularly is it so when the condition is clearing up.

This may possibly account for the fact that some men return to work before they are really cured. In other cases where not only objective but subjective signs also have ceased, nystagmus may again develop in the course of a few years. There must be some central change in the brain, where cells have become accustomed to expending their energy in a particular form, causing rhythmic and constant movements in the ocular muscles; when the man is exposed to conditions similar to those which caused the disease, the old state is soon reproduced, and does not take so long this time, as the cells or nuclei concerned have already developed that particular pathologic faculty. It seems certain that the darkness of the mine is one of the necessary conditions, by weight of much evidence, and as borne out by the ease with which oscillations of the eyes can often be elicited in a dark room, and by the fact that they often cease in daylight.

Table 4 shows the number of years of total incapacity during the second attack, and the number of years before becoming fit for underground work after the second attack. The period of idleness is not very different from the average for the first attack, but the average period before resuming underground work is about six months longer than for the first attack. The inference is that while the second attack is likely to occur in from three to four years after underground work is resumed, it is likely to incapacitate for underground work for about six months longer than the first attack.

I was able to obtain in my series figures for only sixteen cases in which a third attack of the disease occurred. For these cases, the total number of years worked underground after the second attack was 59.25, giving an average of 3.7 years. This period corresponds fairly closely with the average period before the second attack, which was 3.52 years, thus supporting the conclusion that a patient with miners' nystagmus may be expected to work underground some three to four years, on the average, before developing subsequent attacks of the disease and being incapacitated thereby.

TABLE 4.—INCAPACITY FOR WORK WITH A SECOND ATTACK OF MINERS' NYSTAGMUS

PERIOD	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Total incapacity.....	79	82.92	1.04
Total and partial incapacity.....	47	140.50	2.98

Cases with Neurasthenia

In the whole series of 512 cases, there were seventy-one who had definite neurasthenia, a proportion of 14 per cent. These cases cause much diffi-

culty in estimating the incapacity produced by the disease, and it is often a matter of uncertainty to what extent the symptoms are due to genuine neurasthenia and to what extent to malingering. Cases where there was blepharospasm only, with no signs of neurasthenia otherwise, were not included in these seventy-one cases.

In only fifteen of these seventy-one cases were there definite oscillations of the eyes when I examined them. In estimating the capacity for work, it is the general nervous symptoms that are most important in these neurasthenic cases, as contrasted with other cases of miners' nystagmus, where oscillations of the eyes form the chief criterion by which the severity of the disease may be judged.

These nervous cases apparently do not differ from the general average in the age at which the disease develops. The total of years at which disease developed was 2,893, and the average age 40.7. This corresponds very closely with 41.01, the general age for the whole series of 512 cases.

The number of years worked underground in the nervous cases, based on the figures available for thirty cases, was 824 years, giving an average of 27.4 years, which again corresponds closely with the general average of 27.39 years for the whole series.

Cases Developing before 20 Years of Age

There were eleven cases where miners' nystagmus developed in men under 20 years of age, and of this number eight had both eyes normal and three had both defective. This again indicates that defective sight does not influence the early incidence of the disease.

The average length of time spent underground before developing nystagmus was, in three cases, 3.66 years; the least time was two years and six months, in a collier's helper who had defective sight.

The period of total incapacity with a first attack and the period before resuming work underground are given in Table 5. The averages for all types are lower than the corresponding figures for the whole series, which were 1.17 years and 2.41 years, respectively.

TABLE 5.—INCAPACITY FOR WORK WITH A FIRST ATTACK OF MINERS' NYSTAGMUS IN CASES DEVELOPING BEFORE 20 YEARS OF AGE

TYPE OF CASE	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Period of Total Incapacity			
All types	10	8.75	0.87
Both eyes normal	7	4.25	0.60
Both eyes defective	3	4.58	1.52
Period of Total and Partial Incapacity			
All types	7	7.33	1.04
Both eyes normal	5	3.25	0.65
Both eyes defective	2	4.08	2.04

Cases of miners' nystagmus occurring in men under 20 years of age form only 2.1 per cent. of the series, and therefore are not cases of very common occurrence. Although the average periods in Table 5 are based on a

small number of cases, it seems that in these young people the period of incapacity for work with the first attack is definitely less than for the general average case.

The disease, however, seems to recur rather sooner after resumption of underground work. The figures available are for four cases; the years worked underground before the second attack were 7.75, and the average time 1.93 years. This is only a little over half the average time for the whole series, which was 3.52 years. There must have been a predisposition to the disease in these young subjects, which rendered them prone to an early recurrence, although they recovered from the first attack—with their youthful powers of recovery—in a much shorter time.

The average period of total incapacity during the second attack was 0.3 years, based on three cases; this is much less than the period of 1.04 years for the whole series, based on the records of seventy-nine cases, but the number of cases is too small to permit definite conclusions.

In one case only is there a record of the length of time after the second attack before resuming work underground; that time was 0.33 years, which contrasts with the general average time of 2.98 years.

Cases Developing after 60 Years of Age

As a contrast to these cases, and for comparison, I give in Table 6 details of the cases in the series where incapacity from nystagmus did not develop until the men were over 60 years of age. There were 28 such cases—5.5 per cent. of the whole series—9 of which had both eyes normal, 16 both eyes defective, and 2 one eye defective.

TABLE 6.—INCAPACITY FOR WORK WITH A FIRST ATTACK OF MINERS' NYSTAGMUS IN CASES DEVELOPING AFTER 60 YEARS OF AGE

TYPE OF CASE	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Years Worked Underground before Developing Nystagmus			
All types	14	606	43.2
Both eyes normal	5	238	47.6
Both eyes defective	7	308	44.0
Period of Total Incapacity			
All types	21	26.83	1.27
Both eyes normal	6	5.83	0.97
Both eyes defective	13	21.00	1.61
Period of Total and Partial Incapacity			
All types	10	27.83	2.78
Both eyes normal	3	9.33	3.11
Both eyes defective	6	15.91	2.65

In only one case was there a record of the period worked underground before a second attack, which was 1.5 years; the number of years this man was idle with the second attack was 3.5.

These cases had worked underground on an average 43.2 years before giving up work because of nystagmus, whereas in the group aged less than 20, the average time worked was 3.66 years. The influence of defective sight appears to be negligible. The

period of idleness with a first attack and the length of time before being fit for underground work again were slightly above the average for the whole series, and definitely above the average of the cases less than 20 years of age. The figures for average length of time for recovery from a first attack were: cases over 60, 2.78 years; all cases in the series, 2.41 years; cases less than 20, 1.04 years.

In regard to these cases occurring in elderly subjects, it is to be noted that there is often difficulty in distinguishing between symptoms due to nystagmus and those due to age. In many of these cases the complaints are of headache and giddiness. The character of the headache is variously described as a dull ache, or a splitting headache, or a thumping pain at the back of the head. There may be found increased blood pressure, and the thumping pain at the back of the head may be due to this cause, or to a chronic nephritis, and on close questioning one sometimes elicits a history of frequent micturition and having to get up at night.

I have not found albuminuric retinitis in any of the cases, although some have shown a condition of arteriosclerosis of the retinal blood vessels, with thickening of the retinal arteries, and a denting of the retinal veins where they are crossed by the arteries.

Giddiness is also a symptom that is found in subjects of high blood pressure, and in these cases the giddiness is often worse on stooping, as is the case in miners' nystagmus. Furthermore, in elderly men—the subjects of senile decay, or arteriosclerosis—a tremor of the head and hands is not at all uncommon, and when there is added to these symptoms a condition of blinking and some intolerance of light, due to a senile type of conjunctivitis, there exists a series of symptoms which are very similar to those found in miners' nystagmus.

If oscillations of the eyes are present, then it is evident that the man must be suffering from nystagmus; but in many cases oscillations of the eyes may not be found, and these other symptoms have to be considered. To this list of symptoms may be added sleeplessness, irritability, and anxiety.

Some of these patients undoubtedly suffer, not from miners' nystagmus, but from general vascular disease, or chronic nephritis, but usually the man himself is convinced that all his troubles are due to miners' nystagmus and not to any other cause, and it is often very difficult to establish that this is not the case. Thus conditions in the aged favor a continuance of the symptoms of nystagmus, and this probably accounts to some extent for the fact that the period of incapacity for the older men is longer than for those less than 20 years of age.

I have no record of a third attack of nystagmus in a man who developed the disease after 60 years of age, presumably because he would be about 70 years of age before this would develop, and before then he would have been obliged to cease work by reason of his age and his physical condition.

Comparison of Cases Developing in Age Groups 20 to 29 and 50 to 59

The years worked underground in these cases before becoming incapacitated are given in Table 7. These figures show that acuity of vision does not affect the length of time before the

disease develops, as the averages for each set of cases correspond so closely.

The total number of cases in the series aged 20 to 29 was 85, and of these 34 had both eyes normal, and 46 had both eyes defective. In the group aged 50 to 59, there were altogether 113 cases, and 49 had both eyes normal, while 50 had both eyes defective. The two periods now under consideration are about equidistant from the average age at which the disease developed in the whole series, *viz.*, 41.01 years, and a comparison between these two groups is taken so as to get figures for incapacity, to form a check on the apparent differences between those less than 20 years of age and those over 60.

The figures for the period of idleness or total incapacity during the first attack of nystagmus (Table 7) show that the tendency is for the younger subjects to be totally incapacitated for a shorter period than the older subjects, a conclusion that is in accordance with the comparison already made between still younger and still older cases: in the one case, the period is below the general average for the whole series,

TABLE 7.—COMPARISON OF INCAPACITY FOR WORK DUE TO MINERS' NYSTAGMUS IN AGE GROUPS 20 TO 29 AND 50 TO 59

TYPE OF CASE	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Years Worked Underground before First Attack			
Aged 20–29:			
All types	29	299	10.31
Both eyes normal	11	115	10.45
Both eyes defective	17	195	11.47
Aged 50–59:			
All types	43	1,592	37.02
Both eyes normal	17	634	37.29
Both eyes defective	22	803	36.50
Period of Total Incapacity with First Attack			
Aged 20–29:			
All types	61	57	0.93
Both eyes normal	23	30	1.30
Both eyes defective	35	26	0.74
Aged 50–59:			
All types	80	121	1.51
Both eyes normal	33	43	1.30
Both eyes defective	36	59	1.63
Period of Total and Partial Incapacity with First Attack			
Aged 20–29:			
All types	41	64.41	1.57
Both eyes normal	13	19.91	1.53
Both eyes defective	26	41.75	1.60
Aged 50–59:			
All types	42	133.33	3.17
Both eyes normal	15	48.33	3.22
Both eyes defective	22	68.25	3.10
Years Worked Underground before Second Attack			
Aged 20–29	29	86.66	2.98
Aged 50–59	12	34.83	2.90
Period of Total Incapacity with Second Attack			
Aged 20–29	19	.....	0.64
Aged 50–29	9	.....	1.14

and in the other case it is above that average.

The figures for the period after the first attack before becoming fit for underground work again also show that defective vision has no effect on the recovery, and that the incapacity is less prolonged in the younger than in the older subjects—in fact, on the basis of the figures given in Table 7, the incapacity is about twice as prolonged in the older cases, while the general average for the whole series based on 221 cases was 2.41 years, which is about halfway between. These figures therefore support the conclusions drawn earlier.

The periods spent at work underground before again becoming incapacitated by nystagmus are practically equal, so that here age would not appear to be important.

Although only a small number of cases illustrate the period of total incapacity after the second attack, they bear out the view expressed in regard to the first attack. The number of cases illustrating a third attack was too small to be of any value.

Comparison of Cases Developing in Age Groups 30 to 39 and 40 to 49

It was considered that a comparison between the cases aged 30 to 39 and 40 to 49 would be so near the general average age of 41 as to be of no especial significance in determining the influence of age on the course of the disease. The figures, however, bear out the view that acuity of vision has no influence (see Table 8). There were 134 cases between 30 and 39 years of age, and of these 62 had both eyes normal and 63 had both eyes defective. Among those aged 40 to 49, there were 72 with both eyes normal, and 52 with both defective.

TABLE 8.—COMPARISON OF INCAPACITY FOR WORK DUE TO MINERS' NYSTAGMUS IN AGE GROUPS 30 TO 39 AND 40 TO 49

TYPE OF CASE	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Years Worked Underground before First Attack			
Aged 30–39:			
All types	48	986	20.54
Both eyes normal	25	512	20.48
Both eyes defective	17	368	21.0
Aged 40–49:			
All types	56	1,778	31.75
Both eyes normal	25	797	31.88
Both eyes defective	22	721	32.77
Period of Total Incapacity with First Attack			
Aged 30–39:			
All types	105	132	1.25
Both eyes normal	49	63	1.28
Both eyes defective	46	63	1.37
Aged 40–49:			
All types	94	94	1.00
Both eyes normal	50	53	1.06
Both eyes defective	35	26	0.74
Period of Total and Partial Incapacity with First Attack			
Aged 30–39:			
All types	60	154	2.56
Both eyes normal	28	83	2.96
Both eyes defective	27	63	2.33
Aged 40–49:			
All types	59	143	2.42
Both eyes normal	30	76	2.53
Both eyes defective	22	56	2.54

TABLE 8.—*Continued*

TYPE OF CASE	NO. OF CASES	TOTAL YEARS	AVERAGE YEARS
Years Worked Underground before Second Attack			
Aged 30–39	33	.....	3.24
Aged 40–49	34	.....	4.80
Period of Total Incapacity with Second Attack			
Aged 30–39	23	.....	1.17
Aged 40–49	22	.....	0.99
Period of Total and Partial Incapacity with Second Attack			
Aged 30–39	13	.....	2.83
Aged 40–49	15	.....	2.96
Years Worked Underground before Third Attack			
Aged 30–39	5	.....	4.25
Aged 40–49	6	.....	3.65

Cases with One Eye Useless

In the whole series of cases there were twenty-two where one eye was quite useless, and the man was, either actually or virtually, a one-eyed subject. In some of these it was possible to fix a definite date when the eye was rendered useless.

Six cases had had one eye useless from childhood, and the ages at which they developed miners' nystagmus were: 55, 37, 33, 42, 42, and 24 years. In the first three, the healthy eye had a marked error of refraction; in the last three, the error was very slight—in the last case there was 6/9 vision and practically no error. The figures do not conform to the view that a one-eyed subject is likely to develop nystagmus at an earlier age than a man with two useful eyes.

In eleven cases, there was a definite date of an accident which caused one eye to become useless—in some cases as a result of leukoma of the cornea, in others as a result of detachment of the retina, or traumatic cataract, or loss of the eye. The details of these cases are given in Table 9. (In two of these cases, Nos. 10 and 11, the accident occurred before underground work had been commenced.)

Consideration of cases 1 to 9 shows that miners' nystagmus may develop in from two to thirty years after such an injury; but I fail to find any sound relationship between this period and the refractive error in the other eye, even when allowance is made for probable alterations in the refractive error from the date of the injury—such as case No. 9, where it is very likely that at 26 years of age the hypermetropia was less than 2 and probably did not cause defective vision or undue accommodative effort at that time. It seems that there is some other determining factor—possibly a personal idiosyncrasy to the disease, or possibly working conditions in the mine—that is of much more importance than the visual acuity.

One of the men (No. 2), however, developed trouble with his eyes within three weeks of returning to work underground after the accident, and certainly he had by far the most marked refractive error of them all. It is tempting to surmise that the marked error of refraction had a good deal to

do with this, but when this case is contrasted with Nos. 3, 4, and 5, the evidence is not conclusive. It may be that he was one of those men who would have developed nystagmus soon in any case, even perhaps if the accident had been to a finger or some other part of the body.

TABLE 9.—AGE AT WHICH WORKERS WITH ONE EYE DEVELOPED MINERS' NYSTAGMUS, WITH RELATION TO DATE OF INJURY

CASE NO.	AGE AT WHICH MINERS' NYSTAGMUS DEVELOPED	DATE OF INJURY TO EYE	OTHER EYE
		years before	
1	50	2	+1.00D. Sph./+1.50D. Cyl. Axis 90° = 6/9.
2	29	3	−5.50D. Sph./−4.50D. Cyl. Axis 180°.
3	52	4	+1.00D. Sph.
4	41	7	−1.00D. Sph./−0.50D. Cyl. Axis oblique.
5	25	7	Normal 6/9.
6	56	13	+1.25D. Sph. = 6/6.
7	55	17	+0.50D. Cyl. Axis 90°.
8	53	18	−0.50D. Sph.
9	56	30	+2.00D. Sph.
10[1]	44	27	6/9.
11[2]	42	33	+1.00D. Sph./+1.25D. Cyl. Axis oblique = 6/9.

[1] Had worked underground for nine years.

[2] Had worked underground for twenty-five years.

Cases of High Myopia

Consideration of six cases where both eyes had always been very defective from high myopia—over −10 D. of myopia—showed that the average age at which nystagmus developed was 47.5 years. This age is above the average for the whole series, which was 41.01 years; as the six cases included all those with such high myopia, it shows that there is no tendency for high myopes to develop nystagmus early in life: in fact, the figure for these cases indicates that they may be able to continue with underground work a little longer than the average. Four of these cases were colliers and two were hauliers. The youngest case was 36 years of age, and the oldest was 56.

As a contrast to this group, I found fourteen cases where there was no refractive error at all, and vision in each eye was 6/6. Thirteen were colliers, and one was a haulier. The average age at which incapacity resulted from nystagmus was 36 years; —the oldest case was 47, and the youngest 23.

It would be fallacious to argue from this that men with perfect acuity of vision and no error of refraction are liable to develop nystagmus earlier than the average case, for the reason that many of the older men—50 and 60 years of age—might not possess such good vision at that age without the aid of glasses, and therefore would not be included in this category, and on that account the average age for the fourteen cases would probably be less than it really should be.

The absence of evidence that perfect visual acuity influences the age at which the disease incapacitates, does not, however, minimize the evidence of the six high myopes to the effect that such defective sight at any rate does not imply an early occurrence of

miners' nystagmus—an observation that corresponds with the general inferences made by this contribution to the study of the disease.

Figures obtained for the period of recovery from the first attack of nystagmus in the two extreme groups of cases now under consideration showed an average of 3.94 years for the six high myopes, whose average age at onset was 47.5 years, and an average of 1.34 for eight emmetropes with 6/6 vision, whose average age at onset was 31.7. Although the number of cases in these groups is small, it is necessary to investigate these differences, inasmuch as they represent extremes of visual acuity in the series.

I have already drawn attention to a factor to account for the younger age of the emmetropes, which modifies the significance of the figures for these cases; but the period of recovery on the average was three times longer in the high myopes than in the emmetropes. Is this due to the state of vision, or to the differences in the average age? It is to be noted that the average period of recovery for the whole series, based on 221 cases, was 2.41 years, which is approximately halfway between the two, so that the one was distinctly longer than the average and the other distinctly less.

The average period of recovery for 101 cases aged 20 to 39 was 2.16 years; the average for 101 cases aged 40 to 59 was 2.74 years.

In comparison with these figures (and other figures given earlier regarding cases less than 20 years of age and those over 60), it seems that although the age accounts to some extent for the difference in the period of recovery, there is a tendency for the high myopes to take a little longer to recover, and for the absolute emmetropes to take less time to recover.

I would note that the period of recovery in five out of the six myopes was between two and four years, and that in none was it less than two years; while in the emmetropes the period was less than two years in five cases, and between two and two and a half years in the remaining three.

These cases of high myopia are examples of the fact that it is not necessary to have good sight in order to be able to work underground; the conditions of poor illumination, together with the black surface of the coal which absorbs so much light and reflects so little, render macular vision of little actual use for underground work.

As a further example, I will give details of one case. It is that of a man aged 50, who had worked underground since he was 14 years of age. His usual work was that of a hitcher; he developed miners' nystagmus, and on returning to work he continued as an underground laborer until within a month of the date of my examination, when he had to give up owing to a shock he received when a man near him was injured by the pit cage, and not directly on account of his eyesight. Examination of his eyes showed a leukoma adherens in the right eye, with a very tiny pupil, and a central nebula in the left cornea. The left fundus showed extensive choroiditis and there was −11 D. of myopia. The choroiditis was of long standing. Vision was nil in each eye, and the pupils did not react to light. The right fundus could not be seen clearly enough to be sure of its condition,

but such view as was possible indicated that there was gross disease present. He had an internal squint. The condition had evidently been present from early childhood, as he had no knowledge of having had any inflammation of any consequence in his eyes. This man must therefore have worked underground as a hitcher, and later as a laborer, with extremely defective sight, amounting latterly practically to blindness.

I record this case as it is the worst case of defective sight that I have seen in a man working underground. He developed nystagmus at the age of 43, having then worked underground for twenty-nine years. These figures are very near the average figures for the whole series.

Clinical Observations and Illustrative Cases

Factors Determining Onset of Nystagmus

There are various factors that sometimes seem to determine the onset of miners' nystagmus in underground workers. Nervousness and apprehension often cause the oscillations to become evident; in the words of one of the men who was doing underground work, although still suffering from nystagmus, ". . . whenever I see danger, my eyes go round." A sensation of danger induces that reflex attitude of alertness which is the opposite of repose: the eyes are open wider than usual, the muscles toned up ready for a quick response, and the passage of nervous impulses is facilitated as well as the spread of the impulses to surrounding areas. These conditions are ideal for the unmasking of oscillations of the eyes which may not be evident when all is quiet and restful. Similar conditions may be brought about by some physical or mental shock.

Among the men in this series are two who received an injury to one eye two years before becoming incapacitated with miners' nystagmus at the ages of 30 and 38, respectively. In one patient, nystagmus came on two years after recovery from the effects of an explosion which damaged his eyes, face, and body. Two other cases developed nystagmus immediately after injuries, in one case to the head, in the other case to the eye. In these cases, particularly the last two, there was a determining effect for the onset of nystagmus, caused by the injuries received.

Illness may take a similar part in determining the onset of the disease. In one of my cases, influenza incapacitated the man, and then he began to have trouble with his eyes, which proved to be nystagmus.

Another patient, a man who became incapacitated by miners' nystagmus at the age of 53, had been affected by the disease for twenty years before, but had continued at work. He stated that his eyes were always worse after a holiday. In my view, it is often a bad thing for a nystagmus patient who is able to continue at work, to have to cease work for a time; the improvement that might be expected from a short period of rest does not occur, or at any rate on resumption of underground work the trouble with the eyes may be worse than before.

Some of the patients in this series were men who would do all in their power to continue at work while work was available; from what they

have told me, I know that many found it very difficult to keep on working, and they had to rest quietly at home all the time when not at work in order to be fit to endure the trials of the next day.

The influence of family worries is well illustrated by one case, a man who developed nystagmus at the age of 52, and after one year of total incapacity was partially incapacitated for fourteen years by reason of a persistent blepharospasm. He had very genuine family worries, and at the time of the examination, his wife was in an asylum for the mentally defective.

One patient developed nystagmus very soon after having had a shock when a pit cage he was in suddenly dropped a short distance, without, however, causing any physical injury.

Factors Influencing Continuation of Incapacity

The cases cited show how important is the general nervous system in its relation to the problems of miners' nystagmus. In a number of cases the oscillations of the eyes clear up, leaving a state of neurasthenia, which owes its inception primarily to nystagmus. I have been able to observe cases over a period of years and have noted the change.

At first there are oscillations of the eyes, with no general nervous signs. Later, the knee jerks become increased, and the symptoms complained of more general, such as sleeplessness, becoming easily excited and easily startled, with various apprehensions. In the course of another year or so, symptoms of nervousness, tachycardia, giddiness, and intolerance of light become still more pronounced. In these cases I have frequently recommended, in the earlier stages of the disease, that the man should be given work suitable for him; owing to the conditions in the coal industry during the last few years, however, it has often been impossible to provide such work.

I believe that these cases are receiving the worst form of treatment by being allowed to spend their time in complete idleness, with some measure of compensation, which is often quite insufficient to provide them and their families with the necessary food and comforts. The possibility of a cessation of the compensation payments adds further anxiety; and a man develops a curious mixture of feelings of anxiety concerning his bad eyes, and of anxiety lest he should cease to convince the doctor that he still deserves compensation; and, being idle, he has all his time to brood over it and no work to distract him from it. Quite apart from miners' nystagmus, it is a fact that is generally appreciated that work, a definite job that has to be done and attended to, has a beneficial effect on a mind beset and troubled with some of the worries of life. I have remarked on the tendency of the men to attribute various conditions to miners' nystagmus, and among these is defective sight in general.

I have examined many cases where the symptoms of which the man complained were due to errors of refraction, causing some intolerance of light, headaches, maybe giddiness and blurring of the lights underground; and herein lies one of the difficulties in deciding when and to what extent

a man has recovered from miners' nystagmus. If the disease were confined to the objective signs of oscillations of the eyes and no more, it would be comparatively easy to decide when recovery had taken place; but when the symptoms overlap other symptoms which may be caused by refractive errors and other conditions, the problem is much more difficult.

One of the cases was a man who developed nystagmus at the age of 48 years, having worked underground as a collier since he was 11 years of age. I examined him when he was 55 years of age and was suffering from a second attack of the disease; he then showed oscillations of the eyes which cleared up in the next two years. During this time he developed increased knee jerks and a marked head tremor, and showed signs of presenile changes and early paralysis agitans; the general condition was getting worse all the time on this account. In this case the general signs of nystagmus gradually passed on to signs of other nervous disease; and the case serves as an example of the difficulty in deciding where the one ceases to incapacitate and the other begins to do so.

The following is a curious example of how the patient may have genuine grounds for believing that he still suffers from nystagmus when, in fact, the disease has cleared up. The case was that of a man who developed nystagmus at 61 years of age, and four years later he still complained that he became giddy if he moved about and that the lamps at night seemed to move and to dazzle him. He showed no blepharospasm, nor intolerance of light, nor oscillations of the eyes. The right eye had many glistening opacities of cholesterin in the vitreous, but the left eye was clear of such opacities. When the right eye was covered, he said that he felt much better; if his left eye was covered instead, he said that he felt giddy and uncomfortable. In this case I have no doubt that nystagmus had cleared up, and that the cholesterin deposits in the vitreous gave him the impression of lights moving about at night time when the lights were on. Movements of the head and eyes would increase the movements of these vitreous opacities, giving rise to the symptom he complained of—that his giddiness was worse if he moved about.

Character of Oscillations

It is very necessary to have a clear conception of the character of the oscillations of the eyes in miners' nystagmus. My own experience is that the oscillations are of a rotary, or, to use a better term, circumductory, character, and in a typical case the movement of the eyes is uniform in rate and equal in each eye. The oscillations are not necessarily present all the time, and, particularly when a man is on the road to recovery, it may be quite impossible to produce them one day, whereas the next day, or in a week's time, they may be quite easily elicited. The man will often say that he has his "good days" and "bad days." This sometimes accounts for a conflict of medical opinion in regard to the man's recovery from the disease.

Oscillations of the eyes, if not present in daylight, may be evident in a darkened room, and are usually worse on looking upward, but cease on looking well down, unless the case is a

very severe one. This sometimes helps one to decide whether a man is malingering or not, as in a case of genuine nystagmus, with eye symptoms, but without neurasthenia, the patient is more comfortable if he looks down, because then the blepharospasm and oscillations cease. On stooping, the oscillations are usually worse; this effect may be augmented by physical exercise in a stooping position.

There is such a variety of nystagmus cases that one general description will not cover all types, even as far as the eyes are concerned; but the foregoing description holds good in a general way, subject to modifications in individual cases. For instance, it is often the case that, where much blepharospasm is present, the oscillations of the eyes are masked; this does not mean that it is on account of the fact that a view of the eyes is more difficult to obtain while the lid spasm is going on. In many cases I have held the eyelids apart and watched the eyeballs, which show no sign of definite oscillation, although the muscles of the eye may be rather taut and contracted. When the patient can be persuaded to control his lid spasm, the oscillations of the eyes become quite marked. In such a case as this, oscillations and blepharospasm may alternate, and either may be present on stooping or before stooping. As a contrast to this, and to illustrate the variety that the disease shows, there are many cases where oscillations and blepharospasm come on together, and when one ceases, so does the other.

In some cases the oscillations of the eyes are fine, in others coarse. In some the cornea moves in a circle; in others it moves in a horizontal oval; in others it moves in a vertical oval. Sometimes there is a smooth movement of the eyes; in other cases the movement can only be described as violent, and there may be a predominant violence in one direction.

In all these cases, however, my experience is that when the patient is stooping, the movement of the eyes tends to become more regular and rather more in the form of a circle.

As a contrast to the foregoing description, I will give details of two cases I have examined where the nystagmus that was present was not due to mining although it occurred in men working underground in a coal mine.

The first case was an assistant timberman, aged 36, who was said to have suffered from miners' nystagmus six years previously. When I examined him, I found that he had a severe right internal squint, of long standing: the eye was amblyopic, and abduction was very poor. The left eye had −12D. of myopia, with degenerative changes about the macula. The nystagmus was resilient in nature, and the movements were considerably less in the right eye, presumably on account of the defective musculature of the eye. The nystagmus in the left eye showed a quick, jerky movement to the left, with a slower return. When the man looked to the left, the nystagmus was much more pronounced. The same description held good when the man was examined in a stooping position.

The second case was that of a collier, aged 60, who was supposed to have had miners' nystagmus five years previously. He had −8D. of myopia in each eye, and in addition had optic atrophy. He had nystagmus of a resilient nature, with quick jerks of the eyes to the left, and a slower return. The nystagmus became fairly rapid in rate when he looked to the right; when he looked to the left, the movements were slower and coarser, becoming slow, long jerks of the eyes to the left. The

nystagmus was the same when he was in a stooping position. He had no lid spasm nor intolerance of light. I read in my notes that he had had twenty-seven children, mostly premature, of whom only six were now living, a condition of affairs that may have some etiologic relation to the optic atrophy which was present.

These two cases illustrate what I have found in my experience: that no case of miners' nystagmus shows a movement of the eyes that can be definitely described as resilient in nature, and that when there is doubt as to the etiology of the nystagmus present, an absence of aggravation or alteration by stooping is very much in favor of the nystagmus present being due to other causes than mining.

Cases of congenital nystagmus among coal miners are found, and I have seen a few of these cases, generally in order to give an opinion as to whether they were suffering from miners' nystagmus. The movement of the eyes in these cases may not be resilient, and may approximate closely that of true miners' nystagmus. I have found the absence of characteristic alteration when looking upward, when in the dark, or when stooping, of great value as an aid to diagnosis.

Nystagmus of aural origin is mostly resilient in nature; but when occurring in a man who also has undoubted miners' nystagmus, it creates a picture that needs careful analysis. I have records of one such case, in a man suffering from miners' nystagmus, as well as from a fistula in the labyrinth; to complicate the case still further, he had a very severe internal squint from childhood. In this case, giddiness could be produced at any time by pressure on the external auditory meatus. Following are the details of this case, which was one of particular interest:

He had worked underground since he was 12 years of age, as a boy and later as a collier, and had worked underground for twenty-six years when he gave up with miners' nystagmus in 1924. I examined him three weeks later. He complained of headaches, giddiness on stooping, and said that objects seemed to be moving around in circles at a rapid rate. He felt worse on a dull day. He had "always" had a left internal squint, and his right ear had "always been deaf." He had a rotary type of nystagmus, which was increased after stooping and was worse when looking upward. The oscillations were also present when he looked straight ahead.

Seven months later the eyes showed, in addition to a rotary movement, a lateral rhythmic movement when looking to either side. After stooping, the nystagmus became more uniform in type: the movement was not a continuous one in a circle, but a to-and-fro movement in the lower half of a circle, that is, in a semicircle. When he was at rest in a chair, about every two or three seconds there were slow and occasional movements of rotation of the eyeball. No oscillations were present on stooping. There was a history of discharge at times from the right ear, and I suspected that he had a labyrinthitis.

Two months later I examined him again. At that time rotation to the right—stimulating thereby the left labyrinth mainly—resulted in the following "after-nystagmus": *viz.*, on looking to the right, no nystagmus, but on looking to the left there were two types of nystagmus, the one being jerks to the left, the other rotary movements. Rotation to the left—stimulating thereby the right labyrinth mainly—produced the following result: jerky nystagmus to the right on looking to the right, and rotary nystagmus on looking to the left. Spontaneously there was nystagmus (jerks) to the right on looking to the right, with just a suspicion of rotation, while on looking to the left there was rapid rotary nystagmus, such as one would find normally in miners' nystagmus.

There were, however, no oscillations of the eyes on stooping, and the movements of the eyes were much less on looking upward. Just once there was a rotary nystagmus on looking down. Pressure on the right external auditory meatus caused him to fall to the left, indicating that there was a fistula in the right labyrinth.

The differentiation between vestibular and miners' nystagmus in this case was so difficult that it is impossible to be emphatic regarding the conclusions. The absence of rotary movements on stooping or on looking upward, together with the presence of rotary movements once when looking downward, suggests that these rotary movements were not due to miners' nystagmus, but to labyrinthitis.

The rotation tests showed that the left labyrinth functioned normally, with the addition of a rotary movement on looking to the left; in the case of the right labyrinth there was still some function, but on looking to the left rotary movements were present. The rotary movements on looking to the left, which were present spontaneously and after both rotation tests, were similar to the movements of miners' nystagmus, but might be occasioned by labyrinthitis, and I believe, for the reasons given above, that they were due to the latter cause.

Reverting to the oscillations of the eyes in miners' nystagmus, the variability in the extent of the oscillations in different cases is well appreciated. In some cases the oscillations are extremely wide, while in others they may be very fine. As an example of the fine oscillations, the following case is described:

A man aged 52 had suffered from miners' nystagmus for six years, having worked previously as a collier. He tolerated light well, and there was no lid spasm. He was not giddy or nervous. I failed to find any oscillations of the eyes on careful examination, or when he was stooping, or after stooping. He complained of things revolving in the twilight and when he was stooping, however, and as he appeared to be a reliable man, I made further efforts to obtain confirmation of his statements. This confirmation was available on examination with the ophthalmometer; after he had been kept stooping awhile, the eyes, under this magnification, showing a very minute but quite definite and typical oscillation of miners' nystagmus, which was not visible at all to the naked eye.

In other cases I have found oscillations of the eyes when carrying out a direct ophthalmoscopic examination, and in one or two cases the movements have been too slight to appreciate with the naked eye.

Since the traces of the disease may be so slight, it is probable that many cases return to work underground as cured when, in fact, they are still suffering. I have no facts to work on, and I know of no facts, that would show whether a man who is absolutely cured of the disease would be likely to continue at work underground longer before a second attack than a man who is nearly, but not quite, cured, as this patient was.

The rate of oscillation of the eyes varies from about 180 to the minute to 400 to the minute. In four patients seen within a month of giving up work because of miners' nystagmus, the rate of oscillations per minute was as follows: No. 1 (aged 38), 180; No. 2 (aged 36), 400; No. 3 (aged 22), 240; No. 4 (aged 45), 280.

The rate does not show any relation to the age of the patient, but it is influenced by certain other conditions—for example, stooping. The rate of

oscillation in No. 1 was increased, after stooping, to 240, and in No. 4 it was increased to 312. In another case, the oscillations, which were wide and slow on looking upward, became fine and rapid, accompanied by tremor of the head, on stooping, and in numerous cases I have noted that the oscillations were worse on or after stooping.

It is not known why the oscillations are worse on stooping, but there are a few possible causes. When stooping, the eyes are in a dependent position, and so exert a slight pull on the external ocular muscles, and the contents of the orbit tend to respond to gravity, which may exert a slight reflex contraction of the muscles, in the same way that a stretching of a contracted muscle will lead to a contraction of the muscle. The exertion and discomfort of remaining in a stooping position may influence the oscillations, and this part of the examination is often very trying for a nystagmus patient. Then the alteration of the position of the labyrinth is a factor which may be of importance. I have found on many occasions that by producing a vestibular nystagmus, it is possible to elicit oscillations of the eyes as well, in cases where oscillations are not constantly present; shaking the head from side to side a few times will produce a somewhat similar result, so that vestibular sensations certainly influence miners' nystagmus. Generally speaking, anything which produces vertigo is apt to bring on the oscillations of the eyes—for example, looking down when standing on a wagon unloading timber.

Persistence of Oscillations

Six men showed oscillations of the eyes five to six years after the first attack, although they had not worked underground in the meantime. The ages at which miners' nystagmus had developed in these cases, the length of time they had worked underground, and their occupations are given in Table 10. The occupations of these cases are given to show that delay in cessation of oscillations may occur in various grades of underground workers. Case 6, for instance—a laborer—had oscillation of the eyes for six years at least.

TABLE 10.—DETAILS OF CASES SHOWING OSCILLATIONS FIVE TO SIX YEARS AFTER FIRST ATTACK

CASE NO.	AGE AT WHICH MINERS' NYSTAGMUS DEVELOPED	YEARS WORKED UNDERGROUND	OCCUPATION
1	59	47	Timberman for past 35 years.
2	45	34	Collier.
3	48	38	Ripper.
4	49	26	Ripper.
5	46	16	Collier.
6	30	..	Laborer for past 8 years.

The state of visual acuity did not appear to be a factor either, inasmuch as cases 1, 2, and 5 had only a slight error of refraction, case 3 had 3D. of astigmatism, case 4 had an error of refraction of +2D. Sph. in the right eye, and of +1D. Sph. in the left eye, and case 6 had an amblyopic squinting right eye, with a normal left eye.

Case 6 illustrates an observation that I have made in several cases. The right eye had an internal squint,

and the oscillations were worse in this eye than in the sound eye. On stooping, the oscillations were definitely increased in the right eye, but not so much increased in the sound eye.

Another example where the oscillations were worse in the more defective eye is provided by a case which I will now describe in detail:

The patient, E. B., aged 48, had worked underground as a collier for thirty years. I saw him two months after he gave up work with miners' nystagmus.

He had oscillations of the eyes rather badly. His vision then was right eye 6/9, left eye 6/18. The right fundus was normal. The left eye showed a fluid detachment of the retina in the lower part, and he gave a history of a blow on the eye some months previously. Six months later, the left eye was blind, with complete detachment of the retina. The oscillations of the eyes were more marked in the left eye.

In September, 1924, a detachment of the retina appeared in the right eye, and I performed a posterior sclerotomy on this eye, using the electric cautery. When I examined him in July, 1925, there was a posterior polar lenticular opacity in the right eye, but no detachment of the retina. The left eye at this time was blind, owing to complete detachment of the retina, with secondary complete cataract.

Oscillations of the eyes were present on looking up, and were definitely worse in the blind left eye than in the right eye, which now had some useful vision. The oscillations were equal, or approximately so, in each eye until one eye became blind, and from that time they were more pronounced in the blind eye. Apparently the defect in sight was the cause of the difference in the extent of the oscillations in the two eyes.

Nystagmus due to causes other than mining, and rhythmic in type, such as may be seen in nystagmus of optical origin, may also be worse in one eye than in the other, as the following two cases show:

Case 1.—This was an ex-soldier who had high myopia in each eye. Vision with glasses was: right eye 6/36, left eye 2/60. There were degenerative changes around the right macula, but the left eye showed definite changes at the macula as well as in the surrounding area, which accounted for the very poor vision in the left eye even with glasses. He had nystagmus only in the left eye, the rate being 240 to the minute: the movements were rotary in type and rather more horizontal than vertical. They ceased when he looked well to the side, but persisted when he looked up.

Case 2.—This was a boy aged 11, whom I examined in 1927. He had a posterior polar cataract in the right eye, with right internal squint; the left eye was healthy. There was a rhythmic vertical nystagmus present only in the right eye, the left eye being free from nystagmus.

In case 1, the fundus picture furnished an explanation of the presence of nystagmus in one eye only, inasmuch as macular vision in that eye did not exist.

Case 2 is rather less easily explained, as the presence of internal squint made him virtually a one-eyed person, and there was no visible macular disease; the eye was very defective on account of the cataract primarily. It is at any rate a fact that nystagmus was present only in the defective eye.

Thus, it may be concluded that in miners' nystagmus, as in rhythmic nystagmus of optical origin, there are occasional cases where the movements of the eyes are more pronounced in the more defective eye, although this is by no means invariably the case. The fact that it is sometimes the case tends to the view that a good healthy eye, with normal maculae and clear media, can control the oscillations rather more than an eye which has disease at the macula, or is very defective from some other cause; but it does not, as far as my conclusions go,

influence materially the period of recovery from the disease.

The following case illustrates my meaning: A man developed miners' nystagmus at 60 years of age, having worked forty-seven years underground as a collier. His eyesight began to fail two years before he gave up work. He had senile macular changes in each eye and vision was reduced to 2/60 in each eye. In this case one might expect to find oscillations of the eyes for some years if macular disease had much influence on them, but there were no oscillations of the eyes nor any other sign of miners' nystagmus in two years' time. If this man had suffered from macular disease from childhood, he might have been affected by nystagmus of optical origin which would have persisted through life.

There is therefore a fundamental difference between the two types of nystagmus, inasmuch as miners' nystagmus may develop and clear up in spite of a condition of the maculae favorable to the continuation of an optical type of nystagmus. There are also other differences in regard to the character of the oscillations, the symptoms which they cause, and the manner in which they respond to certain tests, as I have already described.

Judging by the facts I have put forward, the wearing of glasses for the correction of refractive errors, in cases of miners' nystagmus, does not hasten recovery from the disease. Glasses should be prescribed for the correction of refractive errors, to relieve the eyes of strain, to relieve headaches or asthenopia and other symptoms, in the same way, and for the same reasons, in patients suffering from miners' nystagmus as in other cases.

Conclusions

1. Defective eyesight in an underground worker does not render him likely to develop miners' nystagmus sooner than a man with good sight.

2. Defective vision has no influence on the average period of total incapacity caused by the first attack of nystagmus, or on the period of recovery from the first attack.

3. The average case of miners' nystagmus, if observed over a period of about nine years after becoming incapacitated by the disease, may be expected to work underground for about three years, and to be totally incapacitated for about two years.

4. There is a definite risk of recurrence of incapacity on the average in three to four years after resuming work underground.

5. The average period of recovery from the second attack is a little longer than that from the first attack.

6. The average age at which the disease appeared was much the same in neurasthenic cases as in other cases, *viz.*, 41 years, and the average period spent at underground work before becoming incapacitated by the disease was, in each case, about twenty-seven years.

7. Incapacity from the first attack of miners' nystagmus, on the average, is less prolonged in young men than in elderly men; but there is no evidence that the elderly men are more prone to a recurrence of the disease.

8. There is no evidence that a man with only one eye working underground is likely to develop miners' nystagmus at an early age.

9. There is some evidence that the average period of recovery from the first attack is a little longer in highly myopic men than in emmetropic men.

10. Illness or injury may determine the onset of miners' nystagmus.

11. There are distinct differences between the character of the nystagmus found in miners' nystagmus and that of nystagmus due to other causes.

12. Oscillations of the eyes in certain cases of miners' nystagmus may be worse in one eye than in the other, as is seen in some cases of nystagmus of optical origin; and this sometimes has a relation to the visual acuity of the eye.

13. The wearing of corrective lenses for ametropia in nystagmus cases, although necessary as in other cases, does not influence recovery from the disease.

AN IMPROVED FORM OF BURSTEIN APPARATUS FOR DETERMINATION OF THE DUST COEFFICIENT OF THE AIR*

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IN 1926, we published the results of an investigation[1] in which we showed, theoretically and experimentally, the inadequacy of the usual gravimetric methods for determining the dust inhaled by man.

Briefly, our conclusions were that the usual gravimetric methods of dust determination, in which the air is drawn through a filtering medium, suffer from one serious defect: They give a representation of the dust content of the air which passes through the filter, but do not necessarily show the true concentration of dust in the air under study.

It is clear that the error is still greater when one attempts, by such methods, to draw conclusions in regard to the amount of dust inhaled by man in a workroom, assuming that the captation of dust from the air by these methods is comparable to the captation of dust by the human respiratory system.

In view of the fact that the determination of the true dust concentration in the air is, in practice, difficult of execution and impossible to accomplish by the methods now in use, we tried to work out a method by means of which it would be possible to determine, not the amount of dust in the air, but the amount actually inhaled by man. To that end, we devised two instruments: a konigravimeter and a specially constructed pump, or "physiologic aspirator."

In our study, we have used the term "dust coefficient" to mean the average amount of dust (by weight) inhaled by the worker during one hour under the conditions of his employment.

As the result of two years' experience in determining the dust coefficient in industry, we can say that a certain amount of training is necessary in order to use the konigravimeter efficiently, owing to the fact that the air inhaled must be inspired through a filter (by the operator)[2]. The pump, on the other hand, can be readily used. It has had, however, one important defect: It could be operated by hand only—a procedure tiring for the operator, who had to make the rhythm of the instrument conform to the rhythm of his own breathing while taking samples. This defect has been corrected in the modified pump which we now use.

* Received for publication Nov. 4, 1929.

[1] Gigiena Truda, 1926, no. 1, p. 27; THIS JOUR., 1928, *10*, 279.

[2] Parenthesis by the editor.

The modified instrument (see Fig. 1) consists in a pump A, which swings[3] on an axle O; the piston rod of the pump is connected with a wheel B in such a way that the end of the piston rod can be fixed at any point in the slit C of the wheel B. In this way, the capacity of the pump can be regulated at will. The wheel rests on the axle O_1. A scale D is placed parallel to the slit in order to measure the capacity of the pump when the piston rod is fixed at different points in the slit. A calculator E is placed under the wheel to register the number of strokes. The arm F attached to the wheel strikes the calculator once for every rotation.

It can be seen from Figure 2 that the axle on which the wheel rests passes through the case G. A gear wheel is fixed to the part of the axle of the wheel which is inside the case. Rod H, to which a worm gear, not shown in the figure, is attached, is perpendicular to the axle of the wheel. A pulley J is connected to one end of the rod. By means of the fitting K, the worm gear can be connected with the gear wheel or disconnected from it at will. If the instrument is to be operated by hand, the worm gear is disconnected from the gear wheel and the driving wheel rotated by means of the handle L, thus moving the piston of the pump.

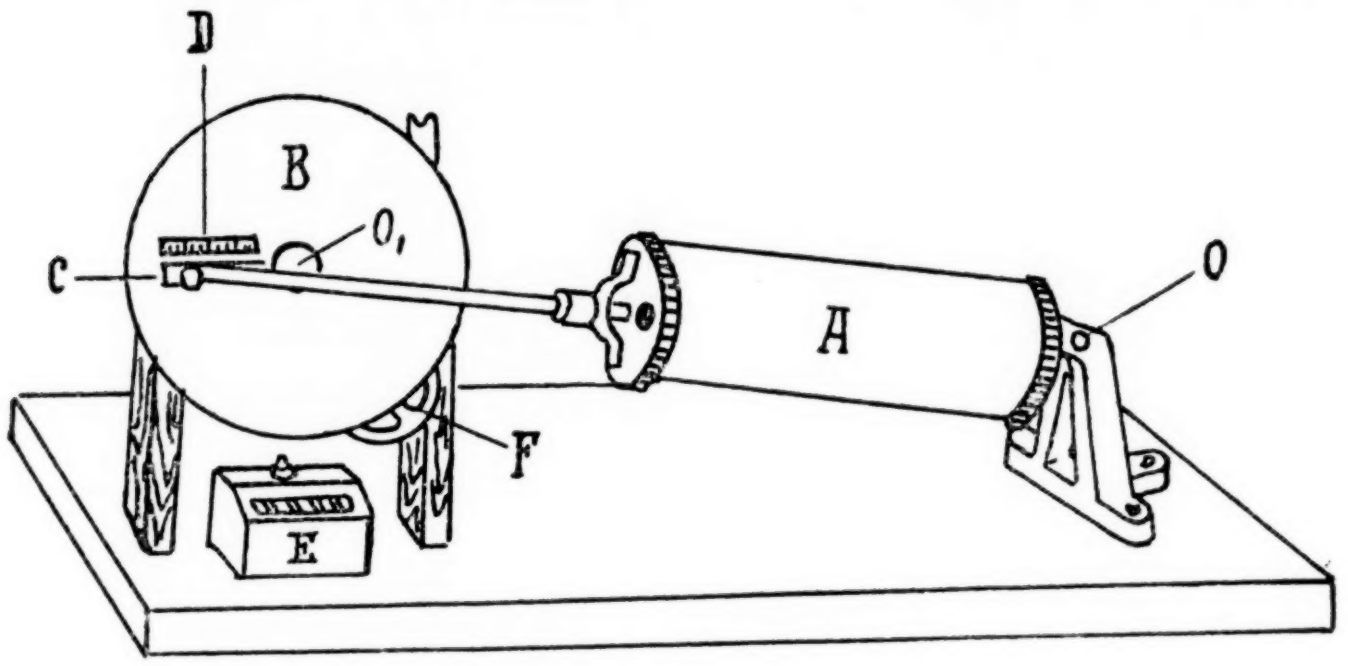

FIG. 1.—Modified pump for determining dust coefficient.

By reading the calculator before the test and at the end, it is therefore possible to determine the number of strokes of the pump. Knowing the capacity of the pump at the point fixed and the number of strokes of the piston, we can calculate the amount of air which has passed through the filter during the test.

If electric power is used, the worm gear is connected with the gear wheel, pulley J is connected with pulley M, to which the axle of the motor N is attached, the handle is removed, and the motor is started.

A short tube leads from the bottom of the cylinder of the pump to the case P, to which two other tubes with ball valves are connected. The lower tube S is for the passage of the inspired air, the upper tube S_1 for the expired air.

[3] The cylinder may be kept stationary by introducing a connecting rod in the usual way.

If direct current is available, it is best to use a variable speed motor, including in the circuit a rheostat *R*, as shown in Figure 2. It is thus possible, by increasing or decreasing the resistance, to regulate the number of strokes per minute of the piston. Regulation is obtained by moving the sliding block *T* of the rheostat according to the indications on the scale *U*.

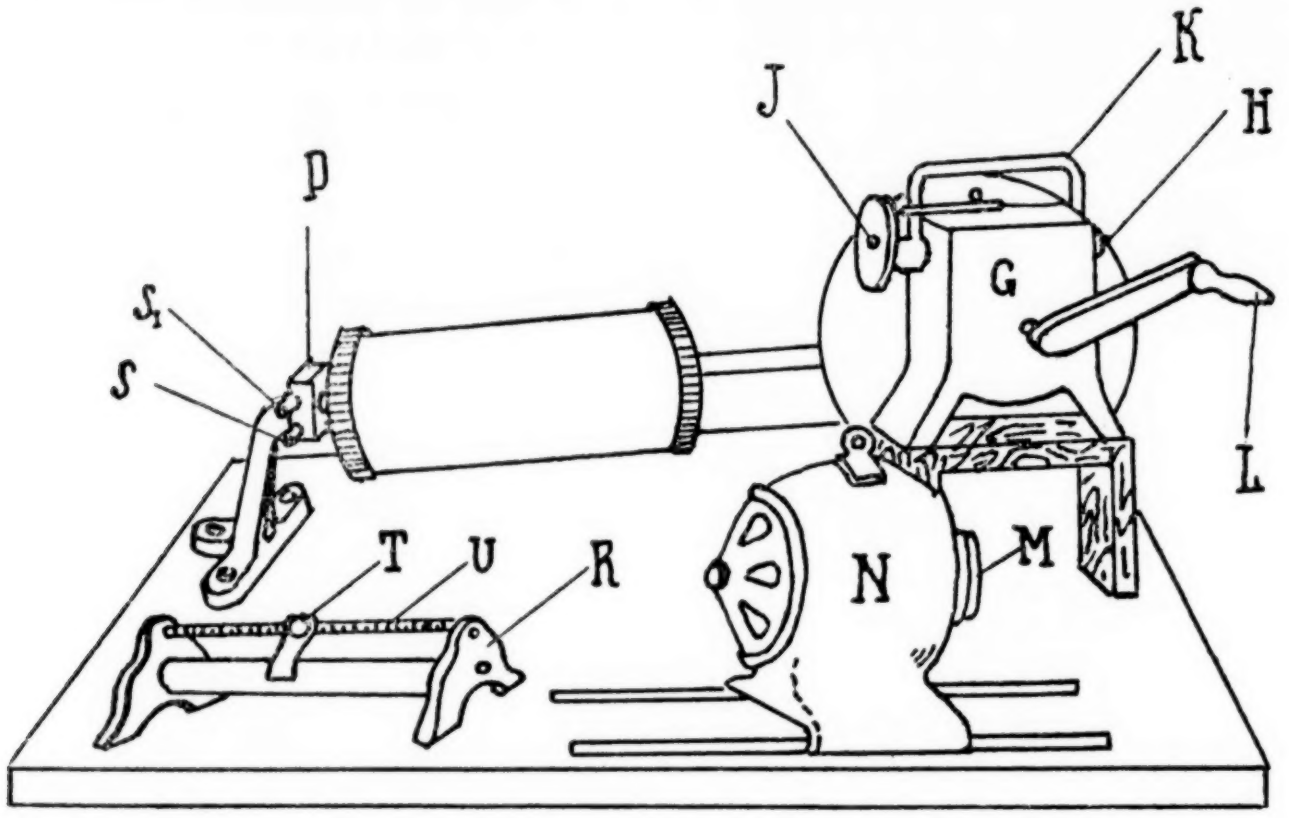

FIG. 2.—Modified pump for dust determinations, showing hand driving arrangement *G*, motor *N*, and rheostat *R*.

If direct current is not available and a constant speed alternating current motor must be used, cone pulleys should be attached to it and to the rod which carries the worm gear. By transferring the belt to pulleys of similar diameter, the strokes of the piston per unit of time can be estimated. Adjustment in this case is accomplished by means of the marks on the separate pulleys, indicating the number of piston strokes.

If electric power cannot be used and the instrument is operated by hand, the operator is limited, in adjusting the instrument to a rate approximating the breathing rhythm, by the fact that he must observe his own rhythm, giving the handle a half turn during inspiration and a half turn during expiration. Thus the accurate regulation which is possible with the use of electric power cannot be achieved, and the rhythm of the pump will only approximate the breathing rhythm of the worker.

The apparatus is somewhat less portable in its present form than it was originally, on account of the addition of a motor—it measures 72 by 42 by 30 cm. and weighs (without motor) 22 kg. —nevertheless it can be transported from place to place with comparative ease.[4] It was constructed at the workshop of the Roentgen Institute of the Odessa County Public Health Department, with the assistance of the Director of the Institute, Dr. E. E. Eram.

The filters and tubes used are similar

[4] We favor reducing the size and the weight of the apparatus.

to those used with the original instrument.

In order to increase the retaining capacity of the filter, it is helpful to wet the cotton wool with about 0.5 c.c. of distilled water, wetting the entire surface of the filter by means of a pipette. This can be done in the laboratory after the filters have been weighed. As was established long ago in the use of sand filters, filtering capacity increases with use, because the dust particles lodge in the filter and close up the spaces. Old filters, therefore, must be specially rated.

We studied filtering efficiency by Aitken's method and also by Tyndall effect and we were convinced that no dust passed through filters prepared in the manner described above. Any particles which passed through would be of the ultramicroscopic order and therefore would have little significance gravimetrically. The important factors here are the density of the filter, the relatively small negative pressure (10 to 140 mm. of water), and the low rate of air flow at the entrance of the filter (18 to 38 cm. per second) with the use of our apparatus.

As yet we have no data to guide us in fixing the rate and the capacity of the pump for determination of dust coefficients in industry. For this purpose it is of great importance that we should know the average volume of air inhaled at each breath and the number of breaths taken in a unit of time by men and women engaged in light, moderate, and heavy physical work.

This problem will be discussed in a separate paper.

MODIFIED DESIGN OF HAY DUST TRAP*

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DESCRIPTION

THIS apparatus, which was originally described in THIS JOURNAL,[1] was devised for the purpose of trapping the dust produced by the hand pneumatic rock drills commonly used in rock drifting operations in coal or metal mines. The principle adopted was that of employing a simple form of ejector, operated by compressed air, to create a partial vacuum in a rubber hood surrounding the hole being drilled and to convey the dust laden air to a suitable filtering device.

The design has been modified recently; the complete equipment is now arranged in unit form which is easily portable (the total weight being about 27 pounds). The time taken to assemble the complete apparatus and to secure it in position is approximately four minutes; once assembled, the apparatus can be fixed in a new position on the same face in thirty seconds.

It can be placed readily in any position in a mine roadway, and by a simple adjustment the suction hood can be set to any point on the rock surface where it is required to drill a hole.

The equipment is of robust and simple construction, designed to withstand the normal amount of rough usage which is unavoidable in mine operations.

The apparatus comprises three principal parts: a telescopic self-securing stretcher bar *A;* a steel suction tube containing the venturi type ejector *B* and fitted with the adjustable rubber suction hood *C;* and a filtering device *D*. (See Fig. 1.)

The stretcher bar consists of two lengths of strong steel tubing of different diameters so arranged that one tube easily telescopes within the other.

The inner or smaller tube is provided with a series of holes $1\frac{1}{2}$ inches apart so that any extension between 5 feet and 9 feet may be obtained. At the extreme end of the inner sliding tube, is fitted an outer sliding sleeve which houses a strong spiral spring permitting compression sufficient to hold the complete stretcher bar rigidly in any desired position.

To insure a free sliding movement when adjusting the stretcher bar, the outer tube is provided at its top end with a gland or collar and the inner tube at its bottom end with a short sleeve.

The extreme ends of the stretcher bar are serrated to insure a firm grip on the rock surfaces and to prevent rotation. Fitted over the larger tube

* Received for publication Nov. 20, 1929.

[1] Nov., 1926, *8*, 496.

is a simple right-angle bracket which carries the suction tube (to be described). The bracket is so arranged that this tube can be adjusted vertically and horizontally and can be rigidly secured.

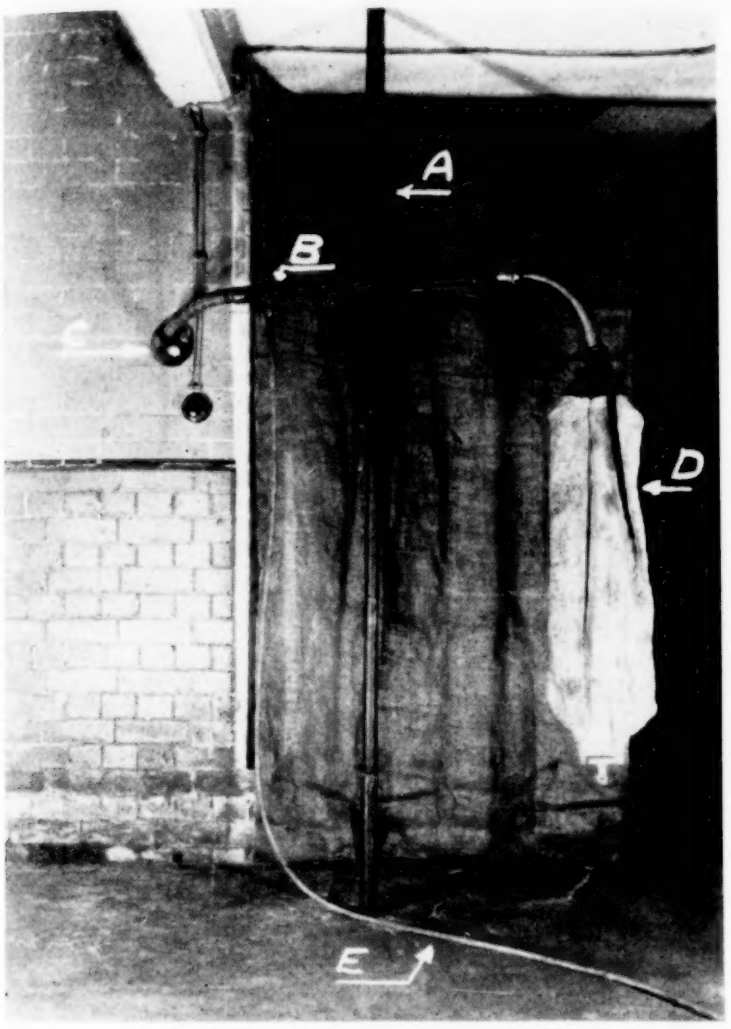

FIG. 1.—Hay dust trap set up as used in rock drilling in mines.

A = stretcher bar; B = suction tube containing venturi type ejector; C = rubber suction hood which can be placed horizontally, as shown, or in either vertical position; D = filtering device; E = compressed air line to ejector.

The suction tube is of light, weldless steel $1\frac{7}{8}$ inches in diameter and 2 feet, 6 inches in length. Into the bore of this tube is fitted a simple venturi type ejector provided with a jet, designed to be operated from the compressed air supply.

At one end of the suction tube is fitted a length of semirigid flexible metallic tubing to which is, in turn, fitted a hood of tough rubber with canvas insertion. The flexible metallic tube is of such construction that it permits setting the hood in any position up to an angle of 90° to the suction tube, and it is of such rigidity that it will remain immovable in any position within these limits.

The rubber hood is provided with a hole to permit the insertion of a drill steel of any desired diameter up to 2 inches.

At the other end of the steel suction tube is fitted a short length of light flexible metallic tubing, and to this flexible tube is attached the filtering device.

The filtering device comprises a bottle shaped bag or trunk of finest quality West of England flannel. All seams or joints are sewed in a special manner to prevent the escape of the finest dust particles. To this flannel trunk, at equal distances around its circumference, are attached four stout straps. These straps run the full length of the bag, thus taking the weight of the contained dust and relieving the flannel from all mechanical strain.

The flannel filter is provided with a cover or envelope of strong twill of such texture that it effectively safeguards the comparatively delicate flannel filter from possible damage.

At the bottom of the filter is an orifice, closed by means of a strong removable steel clip, to permit the filter being emptied as required.

TABLE 1.—RESULT OF DUST COUNTS TAKEN BY KOTZÉ KONIMETER DURING TEST OF HAY MODIFIED DUST TRAP AT LLANBRADACH COLLIERY ON OCT. 16, 1929

SLIDE NO.	POSITION OF SAMPLE	PARTICLES PER C.C.
1	Control spot, before drilling commenced	48
2	Control spot, before drilling commenced	20
3	Control spot, before drilling commenced	106
4	Close to driller's mouth, after drilling for 30 seconds with dust trap in operation	168
5	Close to driller's mouth, after drilling for 1½ minutes with dust trap in operation	76
6	Close to filter, after drilling for 2 minutes and 50 seconds with dust trap in operation	104
7	Close to lower end of filter, after drilling for 5 minutes with dust trap in operation	80
8[1]	Control spot, before drilling commenced, and while new filter bag was being fitted	92
9[1]	Close to new filter, after drilling for 1 minute with dust trap in operation	56
10[1]	Close to new filter, after drilling for 3 minutes with dust trap in operation	44

[1] Taken to determine the efficiency of an improved type of filter bag.

Practical Tests

Exhaustive practical tests underground have demonstrated that this device will effectively trap all the fine dust produced during drilling in either shale or rock.

J. I. H.
Jan., 1930